

UNIDAD EDUCATIVA PARTICULAR JAVIER

MONOGRAPH

**“DEVELOPMENT OF ROBOTIC SURGERY IN THE UNITED STATES:
DEVELOPMENT, ORIGINS AND CASES”**

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Gratitude

Before I begin my monograph, I have a lot of thanks to give, starting by our mighty God, because if it wasn't for him, I wouldn't be in such a privileged school, and wouldn't have the learning opportunities I have today, which a lot of people would wish for. I would like to thank my teacher Patricia Sanchez, and my advisor Glenda Torres, for taking their time in explaining every step along the way to get the best monograph I could write myself. Last but not least, I'd like to thank so much to my parents for making me the person I am today by teaching me and lead me thru the way of good beliefs and a good moral compass. Any of this would be possible without the support of all the people I have mentioned, so thank you all, I love you so much, and never change the way you are.

Summary

The monograph is a summered text about everything involving robotic surgery, specifically in the United States, beginning on the first chapter, where the origins are discussed, including the motivations for it, going back to older times when surgeons there feared by everyone, because of the cruelty and huge dangers involving each and every one of their procedures, as they did not have any good instrumental , and even in not so much old times surgeons still had to perform invasive surgeries that left patients in constant pain for a long time, with huge scars in the site where the procedure was done, so there was the need to find a way of performing surgeries where those consequences where taken out of the equation.

The second chapter is about all the development and research robotic surgery has seen and is expected to have in the next years, again in the United State specifically. The subtopics discussed are two modern machines that are expected to be the future of robotic surgery. The first one is called the da Vinci surgical system, and it is a robot consisting of four arms controlled by a surgeon sitting inside of a console. The second machine is called the CorPath System and it consists of a robot controlled by a surgeon in other place from a VR (Virtual Reality) console, which serves to get help into remote places on Earth. The cases and statistics involving these machines are also talked about.

The third and final chapter focalizes in all the controversies that surround robotic surgery, starting by the problem of its hugely high costs that not everyone can afford, followed by the difficulty of learning how to dominate this machines before the possibility of performing in real time with them, and the fact that robots will end up replacing human surgeons in all their duties at some point.

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The following monograph work is a research about *Development of robotic surgery in the United States: Development, origins and cases*, which not only serves the purpose of teaching robotic surgery history and development over the years, its origins from all over the globe, or the cases involving it, but also the future there is for it, the pros and cons about it, and all the controversies that have surrounded it since its invention, when it was first tested in animals, to present date where it is used in all kind of surgical procedures, either controlled by a human surgeon or working on its own.

The main purpose of this research is to teach everyone, whether their specialized in some branch of medicine, the importance of knowing about the different types of surgeries available, and how robotic surgery is coming to its peak, with new machines appearing every year, with newer and better technologies and features every time, including the costs and whether they are worth the price and/or better than traditional invasive surgery, but explaining everything with statistics, quotes, articles, and proofs, in simple, not technical terms that anyone can understand without the necessity of being a studied in the subject.

This subject has been talked about and discussed by many authors in many different websites or publishers, some of them doctors, and some of them not, for example Alex Lanfranco in his book *“Robotic surgery, a current perspective”*, in collaboration with Andrea Castellanos, John Desai and Walter Meyer. Another example would be Michael Mack in his article *“Minimally invasive*

and robotic surgery” published in 2001. The last reference utilized for this research was

“Schwartz, principles of surgery”, by Frank Charles, although there are many others authors and works on the subject.

Robotic surgery and its idea is dated back to Pittsburg around 25 years ago, when these machines were tested in small animals, getting bigger each time until they were finally used to perform surgical procedures in humans, and it has seen big development since then, getting to the point where robots operate on their own, and this development we talk about has taken place in many different countries with best researchers, (also including the previously mentioned United States) like Germany, France, Denmark, Japan, China, amongst others, and now being used even in third world countries that have the economic possibility to access them.

The monograph is divided in three very specific chapters: the first one will talk about robotic surgery in the United States specifically, discussing its origins dating back 25 years ago and even more, the motivation there was to create it, the dangers it may involve and the better known pioneers of its creation and origins, the second chapter involves the development and research it has seen over the years, also including subchapters that talk about some modern machines, like the case of the da Vinci surgical system, and the CorPath system, including cases and statistics involving both; and the third and final chapter is about all the controversies surrounding robotic surgery, like dangers and high costs it has. (513)

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Chapter I

Robotic surgery in the United States

1.1 Origins

Medicine is an always developing and innovating science, but this monograph will focus specifically on the surgical aspect of medicine. Why is this always changing? Due to people needing more comfort, less pain and less post-surgery recovery time, and lower costs (this goes also for the surgeons). Dating back to the Renaissance, surgeons were pretty much terrifying to anyone, mostly due to the so-called “barber surgeons”.

These people used to travel from village to village performing public surgical procedures, which had to be done in the least time possible because of the agony the patient would go through. A notorious one was Frere Jacques, who is said to have done around four thousands of these procedures.

Then, when thought impossible, anesthesia came into the picture, a magical liquid which would take sensation and sensibility completely out of the equation. So a whole new beginning for surgery took place. Surgeons could perform with a lot less pressure, the patients didn’t suffer pain at all, so they started to reach places that had never been reached before, until patients started dying of infections, in really big numbers.

This continued to happen until the next revolution came around, in the name of Joseph Lister, considered the father and precursor of sterility, because, as simple as it sounds, he made a huge

discovery that dropped the mortality rate in surgeries in enormous quantities, the need of the surgeon to wash his/her hands before and after surgery.

As said by Mack (2001): “Substantial improvements in the art and science of surgery were made over the 150 years since the introduction of antiseptic techniques by Lister, including improved anesthetic agents, antibiotics, surgical nutrition, and organ transplantation (...)” (p. 2).

1.1.1 Motivation.

Surgery advanced to the point where only sky was the limit and discoveries were made more and more every day, but there was a huge problem that could not be resolved, the after marks of a surgery were so big, and the recovery was so long and hard, that the problem had to be addressed urgently. Healthy people didn't need a surgical procedure, and people that did, were too unhealthy for the recovery process. “However, during the last quarter of the 20th century, and especially during the last decade, there has been a paradigm shift in the methods for performance of surgery (...)” (Mack, 2001, p. 3).

So surgery needed to be upgraded, without changing the basics, so how would you do this? Thus, laparoscopy was introduced to the world, and absolutely everything changed inside surgery, Mack (2001) said: “Advancements in video imaging, endoscope technology, and instrumentation have made it possible to convert many procedures in many surgical specialties from open surgeries to endoscopic ones (...)” (p. 1).

Basically any surgery could now be performed in a minimally invasive way through laparoscopy.

Going into details about laparoscopy, it is a method of surgery that consists in cutting little incisions through the patient, where the surgical tools are introduced, and visualized via a small camera that sends its image to a television inside the room.

“The evolution of laparoscopy from a monocular view to the video screen has enabled all in the operating room to see the procedure (...)” (Sackier, 1994, p. 1). Now even patients get a CD with all the surgery recorded on it, which is something that gives them a lot more confidence and trust in the doctors’ procedures when they’re asleep by the anesthesia.

This is just the beginning for robotics in surgeries, due to the growing needs and the advancements in technological fields to compensate them, now robots are close to the point of performing surgeries on their own.

1.1.1.1 Open surgery dangers

Open surgery was not just a much longer and tougher procedure for the surgeon, but it also had a variety of side and aftermath negative effects on the patient. To begin with, the process of making a full opening on someone’s belly for example, took a lot of time, patience and skill from the surgeon, so he could just begin officially with the procedure, which would take a very long time, and as consequence, it would require large quantities of anesthesia, making it all a lot more expensive.

Now talking about the aftermath effects for the patient, it can be highlighted the fact that the procedure would leave very big and probably inerasable scars in the patient body, added to the

fact that the post-surgery recovery will be very long and painful.

The most notorious and worst effect was the mid and post-surgery death rate, which was very elevated, and as high as 1, 9% in a procedure like the gastric bypass, inside the 30 days following the surgery, so experts and surgeons decided that something had to be done immediately to reduce all this consequences for the patients, and to make an easier procedure for the surgeon him/herself.

The methodological innovations in surgery are only beginning. For the first time, it is possible for surgeons neither to look directly at nor touch the tissues or organs on which they operate.

Building on the precedent of pelviscopy in gynecology and arthroscopy in orthopedic surgery, the use of minimally invasive approaches into other surgical specialties. (Mack, 2001, p. 1)

The laparoscopic surgery can sometimes come more expensive than doing a conventional surgery, but it facilitates everything for everyone involved in the process by a lot. So, the biggest problems, pains, discomfort and complications are gained in the process of getting a clear access to the patients organs involved in the surgery (Mack, 2001).

1.1.2 Pioneers.

Georg Kelling was a German internist and surgeon, who is considered to be the first pioneer of the laparoscopic surgery, for performing the first ever known laparoscopic surgery on a dog in 1901.

Hans Christian Jacobaeus was a Swedish internist considered a hugely important figure in laparoscopy, due to the fact that he was the first person to perform a surgery via this method on a

human being. In the following decades, a lot of different experts in the area made discoveries and advancements in this field of medicine, so every time it became easier to utilize and more people were instructed on how to perform surgeries or other medical procedures with it.

One of the biggest events in laparoscopic surgery was when Raoul Palmer, a French gynecologist, made a publication talking about this method of surgery in its new ways.

Then came Hans Frangenheim, a German gynecologist, and Kurt Semm, also a German gynecologist, both considered big pioneers and the fathers of modern laparoscopy, started writing and publishing wonders about laparoscopy based on the results of surgical procedures they had performed on living human patients, of course talking specifically about gynecology in this case.

“The first publication on modern diagnostic laparoscopy by Raoul Palmer appeared in 1947, followed by the publication of Hans Frangenheim and Kurt Semm, who both practiced CO₂ hysteroscopy from the mid-1970s (...)” (Bhattacharya K, 2007, p. 36). These doctors started performing this surgeries at universities and some hospitals, with wonderful results every time, so laparoscopic surgeries became a wonder for everyone in the medical world, from surgeons to patients all around the globe, but of course, this was happening in Europe, and had to take its time to arrive in other countries.

Chapter 2

Development in the United States

Robotic surgery has seen a lot of progress all around the world, with countries competing to an edge on the technological race, but this chapter will focus solely and specifically in the United States of America, and the process it has seen in this so-called branch of medicine.

2.1 Progress and upgrade

Getting more focal in the subject, the United States has been witness to a lot of the most important developments in this area of medicine. Since the da Vinci system was approved, robotic surgery has sky rocketed, being used in a lot of different surgical procedures in a whole lot of different circumstances.

What once was something only thought of and seen in science fiction movies, has now become a reality with more and more inventions coming in every year from different companies and universities. Laparoscopic systems can now be operated by a computer, opening the way for the new generation of robotic surgery.

Although, robotics are not only developing in medicine, as it has also seen a lot of progress in car manufacturing, maybe even faster than in medicine, so we can get the point that robotic surgery hasn't been given the importance as other fields. And why is that? Because it doesn't have the same economic benefits as others.

2.2 Research and Development

As new systems keep coming and breaking more barriers every time, future ones are being developed somewhere else, so that's a reason why we can say that robotic surgery is in its peak in

2019, and will be topped off in 2020. Right now the sky is the limit, and there are some machines that seem to be taken off a science fiction movie, but are real, and will be upgraded and developed more every year.

2.2.1 The da Vinci surgical System.

The da Vinci surgical system is a robotic system created by Intuitive Surgical, an American company. It was finally approved by the Food and Drug Administration (FDA) in 2000. It was designed to make surgical procedures easier, while having a minimally invasive approach towards the patient. It is controlled by a surgeon from a console, and it's commonly utilized for prostatectomies, and it is increasing its use for cardiac valve repairs and also some gynecological surgical procedures.

The company stated that the name “da Vinci” was given in part because of Leonardo da Vinci's studies of human anatomy “eventually led to the design of the first known robot human history”. The machine is composed by four interactive robotic arms that are controlled from the console by the surgeon, who is in the same room as the patient. Three of the four arms are utilized for tools that can hold objects, and can also have the function of a scalpel, a scissor, bovie or graspers. The instrument has a jointed-wrist design that has the benefit of exceeding the natural range of motion of a human hand, plus the reduction of tremor make the hand movement of the surgeon safer for the patient and the whole surgical procedure. Although it still needs a human surgeon controlling every time, it is a major upgrade for conventional laparoscopic surgery, in which the surgeon has to be standing the entire process, holding long-shafted instruments that have no wrists. Also, in conventional laparoscopy, the surgeon has to look at what he/she is doing through

a 2D screen away from the patient that transmits an image recorded by a camera that is controlled by an assistant, so an additional person is needed for the whole process. Due to all these benefits carried by the system, it enable the surgeon with the possibility to perform minimally invasive procedures that involve complex reconstructions or dissections. It also provides the patient with the comforts of less pain, less blood loss and less need of blood transfusion. “Moreover, the da Vinci System can enable a shorter hospital stay, a quicker recovery and faster return to normal daily activities with a lot less pain (...)” (Payne, 2008, p. 13).

2.2.2 The CorPath System.

CorPath is a system developed by the American company called Corindus Vascular Robotics, which consists in a VR (Virtual Reality) system that can be used by a surgeon that isn’t physically present in the surgery site, due to any circumstances that could happen. The VR combines with haptic to help users get tactile feedback, so more realism can be brought when the system is utilized for practice sessions, which is another very big use for the system.

This will have a huge impact in remote places where the people don’t have access to urgent medical care, and also because there’s a lack of skilled surgeons in these areas, so certain procedures can’t be performed, or performed effectively.

There was a recent case in India where a surgeon performed an approximately 15-minute procedure on a patient located 20 miles away. The system was used by the doctor to insert a stent on the patient, while controlling the robot from a distance, and watching everything from a screen.

This machine was recently showcased at EuroPCR 2019 in Paris, France, where it performed a percutaneous coronary intervention (PCI) in front of a crowd of world-recognized doctors and surgeons.

The live case went exactly as planned. I was able to complete the procedure with control of all interventional devices and imaging equipment from the control room, providing my patient with high-quality care while protecting the cath lab team and myself. I am pleased to share this technology with my peers to demonstrate how far it has come, and the promising future it may provide patients. (Fajadet, 2019, p. 2)

This showcase left everyone present impressed with the precision and control levels showed by the machine throughout the complete surgical procedure, and got them convinced on how of an upgrade this is for robotic surgery, and surgery in general as well. Surgical robots controlled by humans, or even self-controlled, can benefit patients who are in a critical condition, and do not have the time or are not in the situation to be transported somewhere where qualified surgeons are available for the procedure (Matthews, 2018).

2.3 Cases and statistics

Going through statistics, robotic surgery seems more safe and legit than before. Beginning with the da Vinci system, 200.000 surgeries were performed with it in 2012, all around the globe. Usually for hysterectomies and prostate removals. As of September 30, 2017, there was an installed base of 4.271 units worldwide – 2.770 in the United States, 719 in Europe, 561 in Asia, and 221 in the rest of the world. Forwarding some years, 693.000 robotic-assisted procedures were performed in 2017. Also in that year, the robotic surgery market was valued at over 2.4 billion U.S dollars.

There are over 2.900 da Vinci systems installed in America, and over 4.500 worldwide, which shows the speed in which this branch of medicine is growing, not only in the United States, but all around the globe.

Chapter 3

Controversies regarding Robotic Surgery

Although robotic surgery has been said to be the salvation and future of modern medicine, it still isn't perfect, and has many disadvantages and controversies surrounding it, regarding different aspects and points of view, which will be explained and discussed in this last chapter.

3.1 Cost of robotic surgery

Getting access to robotic surgery not only comes to the great expense of buying and installing the systems in surgery rooms, but it also comes down to the expenses needed to be addressed to utilize the machines in each surgical procedure. Just to get in perspective, the first robotic surgery ever performed had a cost of around 1 million dollars, but that number has obviously been reduced considerably since then. Today, a robotic surgery machine is estimated and averaged at around 1.4 million dollars, needing an annual maintenance cost of around 120k dollars.

Talking specifically about the Da Vinci surgical system, its cost can go from 500k to 2.5 million dollars, which is a price range that not every hospital can afford and has been heavily criticized by the media and the medial world, even being referred sometimes as "a rip-off". The expenses do not end there, as there is an annual maintenance cost that was mentioned earlier, and in addition, the cost that is involved per procedure, rounding the 3k and 6k dollar range each time it is used, being considerably more expensive than traditional laparoscopic surgery, and even more expensive than traditional surgery.

Surgery is an expensive proposition at the best of times. The high cost of installing a robotic surgery system can increase the cost of a surgical procedure. Surgical robots are costly to maintain, and their operation requires additional training, which is also expensive. Exact numbers are difficult to come by, but in general, a surgery utilizing a da Vinci surgery robot will cost between \$3,000 and \$6,000 more than a traditional laparoscopic procedure. (Nichols, 2019, p.1)

In the unlucky scenario that a machine comes with factory errors, or breaks down suddenly because of any specific reason, the cost of fixing or replacing the broken parts, can become almost as expensive as buying a new one, which is a very big outcome. In addition, there is the cost of having to train surgeons specifically in how to utilize this machines properly, because that is something that isn't always taught at medicine school.

3.2 Learning curve

As said earlier, teaching surgeons how properly utilize machines as the Da Vinci system properly means a big expense that every hospital that wants to use it would have to carry, but it does not end there. The hospitals can pay whatever they have to pay to get the service of professionals in the subject to teach new surgeons everything they need to learn, but it still isn't that easy, because the average surgeon needs around hundreds of experience procedures utilizing the Da Vinci system to be able to completely master it.

All this extra time needed by surgeons to improve their robotic surgery skills, can be put to better use by teaching more doctors in less time other things like specific techniques on manual or traditional surgery, because surgeons won't be able to effectively perform surgeries on this

system until they have totally mastered it.

To put this in perspective, there was the need to create a secondary Da Vinci system for educational and practice purposes only.

3.3 Possibility of malfunctions

Just like any electronic or robotic system, even outside medicine, they always have a tendency to fail, malfunction or collapse in an inappropriate moment, as the Murphy laws state, “Anything that can possibly go wrong, does”. One of this machines breaking down can mean a huge loss of time for the hospital, and possibly huge numbers of deaths. That is why hospitals that want to implement this systems, have to always be ready in case any misfortune occurs, because robotic surgery may have a smaller error margin than manual human surgery, but it still isn’t perfect, or near it.

3.3.1 Movement latency.

Another problem with this systems, is that a surgical invasive procedure is such a delicate process that has to be performed with such a precision as much in movements as in time, and there comes the problem, because with this systems, there is a small time gap between the moment the surgeon sends the signal, and the moment the robot performs the action, so as small as that time can be, it can be critical when performing any type of surgery. “The time it takes for the robot to carry out the surgeon's commands. It takes a few moments for the computer to communicate with the robotic arms (...)” (Nichols, 2019, p.2).

3.4 Human replacement

This is not a big problem just yet, because the robots are controlled by humans, and that means it doesn't take them their job away, but this might happen in the future with the improvements that are coming to robotic surgery, because human surgeons will be less needed every time, until the day arrives that robots will perform surgeries completely on their own, and human surgeons won't be needed anymore, meaning a huge unemployment rate in such a demanding career as medicine is all around the world.

All the years of studying that doctors went through, ranging from 7 to 20 years, depending on the post grade, will practically be useless after some years of robotic surgery development, because hospitals will be demanded to upgrade to this new methods, and doctors already working there were not taught on how to perform surgeries utilizing this machines or systems, and that's in the case that they are still needed in the procedure.

3.5 Weighing advantages and disadvantages

Although robotic surgery counts with a big number of disadvantages, there is no doubt that this is all for good, and change is always necessary, as millions of years of existence have proven to us, and it will end up adapting and being alright with the needs and demands of everyone, as much to doctors as to patients. With this branch of medicine being managed and developed correctly in years to come, the advantages should overcome the disadvantages by a landslide, as the cost problem should change for good, and the movement latency should be improved (Nichols, 2019).

Conclusions

After concluding this monographic work, it is safe to say that:

- Robotic surgery is the future of medicine, receiving recognition, attention and a lot of research all around the globe, knowing that medicine is an always changing science in which you have to be adapting every year, or else you will be stuck in the past not being able to progress as a doctor.
- This branch of medicine, or method of surgery, was something absolutely necessary in the medicine world, because patients in ancient time had a very big chance of dying when entering a surgical procedure, and not only in the process of the surgery, but many times in the following recovery days, because of the big invasive procedures needed to get inside of the patient, so a minimally invasive method of surgery was a moat, giving place to robotic surgery.
- Robotic surgery was not created by one specific man. It is the process of many different researches and experiments from many different doctors across many years, each and every one of them finding an error and a success in each test they performed, so all these results could be taken and studied in the future, and that is how modern day machines were created, and the reason they are so accurate.

- method has gotten so advanced, that there are no longer only machines that have to be controlled by a surgeon sitting in another room, but now there also exist machines that can perform, and with great success rate according to the statistics (maybe even better than human surgeons), any kind of surgical procedure according to the situation where these can be needed.
- Anything is perfect, including robotic surgery, as there are many controversies surrounding it. The first one being the extremely elevated cost that has to be paid to have the access to one of these machines, not even including the cost to utilize it, and the maintenance cost in a case of emergency. Second, the high learning curve it has to any doctor before being able to master it, and last, but not least, the fact that these robots one day will end up totally replacing human surgeons, augmenting the unemployment problem and social crisis that our world currently lives on.

Recommendations

At the end of the monographic work, it is recommended that:

- Every person that is considering or needs to be involved in a surgical procedure, investigates and learns about the different method there are of surgery, the pros and cons of each one, and which one will fit the patient better, considering safety, costs, recovery, etc.
- Doctors, specifically surgeons, must be prepared to learn, not only utilizing, but to master this machines like the da Vinci surgical system or the CorPath System to mention some, as soon as they graduate form medicine school, because this will probably be the only way they will perform surgeries during their entire career, if they can find a job.
- Always trust your doctor and whatever advice they give you on how you should have surgery, when surgery is needed, and the instructions you are given for post-surgery recovery, because they are the specialists that know about the subject more than anyone around, due to all the years they have put to educate themselves and getting the doctor degree.
- Read, to always be conscious about any development, or any discovery that could be made in medicine, as it is something that affects everyone of us, and it is always being researched.

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